FINAL TECH MEMO
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BAY DELTA CONSERVATION PLAN: Proposed Interim Delta Survival Objectives for Juvenile Salmonids

NOAA Fisheries, Southwest Region, Central Valley Office

EXECUTIVE SUMMARY

The purpose of this memorandum is to introduce Interim Juvenile Salmonid Delta Survival Objectives (Interim Survival Objectives) and to explain the process used to develop them. Bay Delta Conservation Plan (BDCP) covered salmonids are defined as winter-run, spring-run, fall-run and late-run Chinook salmon and steelhead spawning in the Sacramento and San Joaquin rivers. Although empirical data on current through-Delta survival for each of the covered salmonids are not available, there are some survival data for selected species on which to base initial survival objectives for the BDCP to make a meaningful contribution to recovery. This memo also serves to introduce a framework for revising and refining objectives for Delta survival. The objectives presented are interim, and will be refined as additional data become available. These BDCP survival objectives would provide 50% of the total improvement in overall survival necessary to meet target cohort replacement rates (CCR). The remaining 50% of the necessary improvements in juvenile survival are expected to be achieved through recovery actions distributed throughout the salmonid life-cycle.

A simple deterministic, stage-based life cycle model and ultimate CRRs of 1.4 for spring-run, fall-run, late fall-run Chinook salmon and steelhead, and 1.5 for winter-run Chinook salmon were used to develop the Interim Survival Objectives. We established a progressive schedule of intermediate CRR targets through the span of the BDCP permit period to simulate the expected progressive improvements in salmonid survival as BDCP benefits are realized through plan implementation. This timeline starts with the signing of the Record of Decision (Year-0), with the primary benefits from BDCP implementation expected to commence following initial operation of the North Delta Diversion in Year-10. Using average fish generations (3-years) as the unit of time, we identified intermediate time steps at BDCP Year-19 (three generations after initiation of dual conveyance) with a CRR target of 1.2; Year-28 (another three fish generations) with a CRR target of 1.3; and a final time step at Year-40 (four more generations) with a CRR of 1.4, for spring-run, fall-run, and late fall-run Chinook salmon and steelhead. CRR targets of 1.3, 1.4, and 1.5 at the same respective time steps were used for winter-run Chinook salmon based on recognition of their endangered status. The intermediate and final Interim Survival Objectives relating to these CRR targets are summarized in **Table 1** below.

Current Delta survival estimates for Chinook salmon and steelhead originating in the Sacramento River range from 0.35 to 0.50. The calculated Interim Survival Objectives for winter-run Chinook salmon are 0.52, 0.54, and 0.57 for the BDCP Year-19, -28 and -40 time steps, respectively. For spring-run Chinook salmon, the calculated Interim Survival Objectives are 0.49, 0.52, and 0.54,

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respectively. The calculated Interim Survival Objectives for fall-run Chinook salmon are 0.42, 0.44, and 0.46, respectively. The calculated Interim Survival Objectives for late fall-run Chinook salmon are 0.49, 0.51, and 0.53, respectively. Using a current survival of 0.45, the calculated Interim Survival Objectives for Sacramento River steelhead (Battle Creek population) are 0.54, 0.56, and 0.59 for the BDCP Year-19, -28, and -40 time steps, respectively. The Battle Creek population was selected as representative of Sacramento River steelhead, as the survival studies will likely use hatchery steelhead smolts from Coleman National Fish Hatchery, which is located on Battle Creek.

Current Delta survival rates for Chinook salmon and steelhead originating in the San Joaquin River range from 0.02 to 0.10 (VAMP Annual Reports, R. Buchanan pers. comm.). For fall-run Chinook salmon current survival was set at 0.05 and the calculated Interim Survival Objectives are 0.27, 0.29, and 0.31 for the BDCP Year-19-year,-28, and -40 time steps, respectively. Using an initial survival estimate of 0.07, the calculated Interim Survival Objectives for San Joaquin spring-run Chinook salmon are 0.33, 0.35, and 0.38, respectively. For San Joaquin steelhead, the current survival was set at 0.10, and we calculated Interim Survival Objectives of 0.44, 0.47. and 0.51, respectively. NMFS anticipates periodically reviewing and updating these Interim Survival Objectives as new empirical data become available, and plans to work collaboratively with resource agencies and stakeholders to monitor progress toward meeting the objectives.

For all species, these Interim Survival Objectives represent 50% of the estimated increase in Delta survival required to achieve the modeled CRRs, based on improvements in through-Delta survival alone. That is, we held pre- and post-Delta survival constant, and calculated the improvement in Delta survival needed to achieve the target CRRs, and assigned half of that improvement as the objective for BDCP conservation measures. The balance of the improvements required to achieve the modeled CRRs are expected to be derived from other recovery actions distributed throughout the entire range of covered salmonids, which could occur upstream, in the Delta, or in the ocean.

Table 1. Estimated current Delta survival rates and proposed Interim Delta Survival Objectives for each of the BDCP covered salmonids.

Species	Population	Estimated Through-Delta survival	Interim BDCP Delta Survival Objectives: after 19 years	after 28 years	after 40 years
Chinook salmon	Sac winter-run	0.40	0.52	0.54	0.57
	Sac spring-run	0.40	0.49	0.52	0.54
	Sac fall-run	0.35	0.42	0.44	0.46
	SJ fall-run	0.05	0.27	0.29	0.31
	Sac late fall-run	0.40	0.49	0.51	0.53
	SJ spring-run	0.07	0.33	0.35	0.38
Steelhead	Sacramento	0.45	0.54	0.56	0.59

	San Joaquin	0.10	0.44	0.47	0.51

INTRODUCTION

Chinook salmon and steelhead in the Sacramento and San Joaquin rivers have been in decline for over 100 years, and two Evolutionarily Significant Units (ESUs) of Chinook salmon (Sacramento River winter-run and Central Valley spring-run) and a single Distinct Population Segment (DPS) of steelhead (California Central Valley) are listed as threatened or endangered under the federal Endangered Species Act. Two additional populations of Central Valley Chinook salmon (fall-run and late fall-run) have been combined in a single ESU by the National Marine Fisheries Service and are currently classified as a Species of Concern.

One of several factors responsible for salmonid decline and limiting their recovery is high mortality of juvenile salmonids as they pass through the labyrinth of canals, channels, and sloughs comprising the Sacramento-San Joaquin Delta (hereafter the Delta). Water quality and physical habitat in the Delta have been severely degraded over time, and populations of non-native predators have become well established. Exacerbating the perilous journey through the Delta are the two industrial scale pumping facilities located in the southern Delta that provide water for a large portion of California's human population and irrigation of arid agricultural lands located in the country's most populous state. Not only are fish entrained at the pumping facilities, but the sheer volume of water exported can substantially affect the hydrodynamics of the central Delta.

In order to make a meaningful contribution to recovery of Central Valley salmonids, NMFS is working with interested parties to develop the Bay Delta Conservation Plan (BDCP). A key component of the BDCP is establishment of biological goals and objectives which will help guide conservation measures and the adaptive management process. Among these goals and objectives, one of the most important is the effort to improve migratory conditions and survival of juvenile salmonids passing through the Delta. Additional BDCP actions, such as efforts to restore salmonid habitat in the Delta and improve overall ecosystem productivity, will also be considered as measures contributing to recovery, but have separate objectives not considered here.

The purpose of this memorandum is to introduce Interim Juvenile Salmonid Delta Survival Objectives for each of the BDCP covered salmonids and to explain the approach used to develop these Objectives. Although empirical data on through-Delta survival for each of the covered salmonids are not available, there are survival data for selected populations and life stages, and in total there exists a body of information upon which to base initial scientific judgments about baseline survivals and the percentage improvement required for the BDCP to make a meaningful contribution to recovery. An equally important purpose of this memorandum is to introduce a simple deterministic, stage-based life cycle approach to define BDCP objectives, periodically review and update them, and monitor progress toward achieving the intermediate and final Cohort Replacement Rate (CRR) milestones. Although further consideration and effort is needed to inform these targets, it is imperative to establish interim objectives in order to guide monitoring and the management decision-making process in the near term.

BACKGROUND

Species and Populations. There are four generally recognized runs of Chinook salmon in California's Central Valley that are endemic to either the Sacramento or San Joaquin rivers, or both: winter-run, spring-run, fall-run, and late fall-run Chinook salmon (*Oncorhynchus tshawytscha)*, and multiple geographically defined populations of steelhead *(Oncorhynchus mykiss) (Meyers et al*. 1995, Busby et al. 1996). For the purposes of the BDCP, covered salmonids are defined as winter-run, spring-run, fall-run and late fall-run Chinook salmon, and steelhead spawning in the Sacramento and San Joaquin rivers (collectively referred to as California Central Valley Steelhead). As noted above, the Central Valley spring-run Chinook salmon ESU is listed as threatened and the Sacramento River winter-run Chinook salmon ESU is listed as threatened. Spring-run Chinook salmon were historically present in both the Sacramento and San Joaquin rivers but have been extirpated from the San Joaquin and will be reintroduced over the next several years. Historically, winter-run Chinook salmon were only present in the Sacramento River, spawning in the upper tributaries above the current location of Shasta Dam. Fall-run Chinook salmon are present in both rivers. It is uncertain whether the San Joaquin River ever supported a late fall-run Chinook salmon population (Yoshiyama et al. 1998).

As defined by their Endangered Species Act (ESA) listing, the Sacramento River winter-run Chinook salmon ESU includes all naturally spawned populations of winter-run Chinook salmon in the Sacramento River and its tributaries, as well as winter-run Chinook salmon reared at the Livingstone Stone National Fish Hatchery. Designated critical habitat for the Sacramento winter-run Chinook salmon includes: the Sacramento River from Keswick Dam downstream to Chipps Island at the westward margin of the Sacramento-San Joaquin Delta, all waters from Chipps Island westward to Carquinez Bridge, and all waters of San Pablo Bay north of the San Francisco/Oakland Bay Bridge.

The Central Valley spring-run Chinook salmon ESU includes all naturally spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries in California, including the Feather River. One artificial propagation program, the Feather River Hatchery spring-run Chinook salmon program, is considered part of the ESU. Designated critical habitat for the Central Valley spring-run Chinook salmon ESU includes 1,158 miles of stream habitat in the Sacramento River basin and 254 square miles of estuary habitat in the San Francisco-San Pablo-Suisun Bay complex.

The California Central Valley (CCV) steelhead DPS includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries. Two artificial propagation programs – the Coleman National Fish Hatchery and Feather River Hatchery steelhead programs – are considered to be part of the DPS. Designated critical habitat includes 2,308 miles of stream habitat in the Central Valley and an additional 254 square miles of estuary habitat in the San Francisco-San Pablo-Suisun Bay complex.

Life histories. From a life history perspective, California's Central Valley supports perhaps the most diverse populations of Chinook salmon in the world. Named for their adult run-timing, but displaying substantial diversity throughout their life cycles, the four runs of Chinook salmon and Central Valley steelhead enter the Delta at different sizes, at different times, and reside for variable time periods, although there is overlap among populations. **Table 2** summarizes life history information for the covered salmonids based on information synthesized from a variety of sources, including Vogel and Marine (1991), Fisher (1994), and Williams (2006).

Current Delta Survival Estimates. Despite efforts by many researchers to estimate juvenile salmonid survivals in the Delta over the past several decades, only recently have the necessary tools and statistical models become available to rigorously address the task. At this time the most robust Delta survival estimates are limited to late fall-run hatchery Chinook salmon emigrating from the Sacramento River, and to a lesser extent fall-run hatchery Chinook salmon emigrating from the San Joaquin River. However, population-specific estimates are needed for all Chinook salmon and steelhead populations migrating from the Sacramento and San Joaquin rivers. Accordingly, these initial survival objectives and the percentage improvements are necessarily interim, with the expectation that they will be revised as new empirically derived survival estimates become available. The following are brief summaries of the studies that were considered in developing baseline survival estimates.

Michel 2010 – Estimated survival of Sacramento River juvenile late fall-run Chinook salmon for three consecutive years between 2007 to 2009 using acoustic tag methods; 200 to 300 fish were tagged and released per year and detected at multiple locations during their downstream migration. Late fall-run Chinook were selected because of their availability at Coleman National Fish Hatchery as yearling smolts at a size large enough to carry an acoustic tag (minimum size 160 mm). In 2007, tagged fish were released into Battle Creek at Coleman National Fish Hatchery in January. In the two subsequent years tagged fish were released in the upper mainstem Sacramento River in January. Final detection locations were at the Golden Gate Bridge, at which point the migrants were considered to have entered the ocean. Total survival from RKm 518 to RKm 2 ranged from 3.1 to 6.1%; the 3-year average was 3.9%. Partitioning the migration route into sections, the upper reaches (RKm 581 to 325) supported the lowest survival; the lower riverine reaches supported the highest survival (RKm 325 to 169); and the Delta and estuary (RKm 169 to 2) supported intermediate lower survival. Based on an estimated 93.7% survival per 10 Km of Delta (RKm 169 to 70), Delta survival was 52.6%. This estimate is consistent with those of Perry et al. cited below.

Perry et al. 2009; Perry 2010; Perry et al. 2012a; Perry et al.2012b – Estimated Delta survival of acoustically-tagged late fall-run hatchery Chinook salmon in a series of studies conducted between 2007 and 2010. Survival estimates ranged from a low of 0.174 (SE 0.031) for a release made in December 2007 to a high of 0.543 (SE 0.070) release made in January 2007. The arithmetic average of ten survival estimates was 38%. Most of these releases were made in relatively dry water years (except for 2010), but still represent some of the best estimates of Delta survival presently available, and were used to select baseline survivals of 0.40 to 0.50 for Sacramento River Chinook salmon and steelhead for the purposes of developing interim survival objectives.

Kjelson and Brandes (1989) and Brandes and McLain (2001)—Working under the Interagency Ecological Program for the Sacramento-San Joaquin Delta (IEP), conducted numerous mark-recapture studies in the lower Sacramento River, lower San Joaquin River, and Delta beginning in the early 1970s. Based on available technology and methods they used single- and paired-releases of coded-wire-tagged hatchery fall-run Chinook salmon and relied on a mid-water trawl near Chipps Island and Antioch and ocean harvest data for recapture locations/sources. Paired-release estimates were reported as relative survivals, whereas single release estimates were reported as "survival indices." Although results of these studies, summarized in Kjelson and Brandes (1989), Brandes and McLain (2001), Newman and Rice (2002) and Newman (2008) made a substantial early contribution to understanding survival bottlenecks in the Delta, the more recent studies employing acoustically-tagged smolts have yielded more precise information on Delta and within-Delta route-specific survivals. In general, the recapture rates of coded wire tagged (CWT) fish in all of these studies were quite low, and survival estimation required multiple assumptions regarding recovery efficiency. Accordingly, NMFS placed greater emphasis on the more recent estimates to inform selection of baseline survivals. However, even acoustic telemetry estimates are not without limitations. For instance, survival measured using acoustic tags can be biased high if tagged fish are eaten by predators that subsequently move past receiver locations.   Presently, there is no definitive way of determining if a tag detected at a receiver is in a live target species or in a predator.

VAMP Studies—Are a series of studies conducted under the aegis of the Vernalis Adaptive Management Program (VAMP), and provide the best available insight into survival of San Joaquin fall-run Chinook salmon during their sojourn through the Delta. A cornerstone of the San Joaquin River Agreement (SJRA) and commitment to implement the State Water Resources Control Board (SWRCB) 1995 Water Quality Control Plan (WQCP) for the lower San Joaquin River and the San Francisco Bay-Delta Estuary, the VAMP studies were initiated in 2000 and conducted annually through 2011. A primary objective of the VAMP was to document how salmon survival changes in response to alterations in San Joaquin River flows and State Water Project (SWP)/Central Valley Project (CVP) exports with the installation of the Head of Old River Barrier (HORB). Studies conducted through 2006 employed CWT hatchery fall-run Chinook and Chipps Island mid-water trawl recoveries to estimate survival. Because of a shortage of hatchery fish and concern over high incidental take of Delta smelt in the mid-water trawl, the approach to estimating survival shifted to acoustic tagging and a release-detection framework to estimate survival, route selection, and detection probabilities among three migration pathways through the Delta. Results from 2010 and 2011 were considered to establish baseline Delta survivals of San Joaquin Chinook salmon and steelhead of 0.05 and 0.10.

GENERAL APPROACH AND ASSUMPTIONS

Meaningful improvements in Delta survival of juvenile salmonids must be measureable and contribute to recovery. Accordingly, baseline survivals must be established and routine monitoring implemented to track progress toward achieving the survival objectives. Because migration through the Delta is only one of several life stages where survival improvements will be required for species recovery, many additional studies and detailed life cycle models will be required. These studies are needed to identify life stage-specific survival rates, prioritize opportunities to improve life stage-specific survival rates, and ultimately the needed changes throughout the freshwater, estuarine, and ocean phases of the salmonid life cycle that will allow recovery of these species. Furthermore, actions not directly linked to Delta survival, such as supporting life history diversity and improving salmon growth and condition while emigrating, may also contribute to recovery. There is limited scientific understanding to weigh and compare effectiveness of such actions, which necessitates a flexible initial approach when allocating recovery efforts.

Although detailed, species-specific life cycle models are a preferred method of estimating the contributions of habitat changes and changes to life stage-specific survival, particularly in the context of recovery, those available at this time have limitations when focusing on the BDCP actions. For example, the Oncorhynchus Bayesian Analysis (OBAN) Model is just now being modified to consider reduced Sacramento River flow expected with construction and operation of a North Delta Diversion. As a retrospective statistical model, any predictions it makes based on conditions outside of those observed could have low confidence. The Interactive Object-Oriented Simulation (IOS) Model appears somewhat insensitive to changes in environmental conditions. Neither model uses empirical survival estimates from Red Bluff Diversion Dam to the ocean to validate their results, as survival to the ocean is not measured. Finally, results from the two models, as reported in the BDCP Effects Analysis of February 2012, were not consistent; whereas OBAN predicted significant impacts from increased upstream water temperatures, IOS predicted declines largely due to changing conditions in the ocean. Ongoing efforts will be focused on further development and application of these and other models to inform revisions to current objectives. Furthermore, through the adaptive management process and monitoring further development of objectives will occur.

Accordingly, to develop these Interim Survival Objectives we employed a simplified Excel spreadsheet approach in which we divided the life cycles into Pre-Delta, Delta, and Post-Delta life phases and assigned average survivals to each phase (**Table 3**). By populating the model with species-specific fecundities and selecting target CRRs that will substantially contribute to recovery, we estimated changes in Delta survivals needed to achieve the target CRRs at multiple time steps. To monitor progress, we established a BDCP timeline for interim and final CRR targets beginning with the signing of the Record of Decision (Year-0), and construction and initial operation of the Northern Delta Diversion to support dual conveyance beginning in Year-10. Using average fish generations (3-years) as the unit of time, we identified intermediate time steps at BDCP Year-19 (three generations past dual conveyance) and a CRR target of 1.2; another intermediate time step at

Year-28 (another three generations) and a CRR target of 1.3; and a final time step at Year-40 (four more generations) and a CRR target of 1.4, for spring-run, fall-run, and late fall-run Chinook salmon and steelhead. CRR targets of 1.3, 1.4, and 1.5 at the same respective time steps were used for winter-run Chinook salmon based on recognition of their endangered status. These CRR targets were selected to put the covered salmonids on a population growth trajectory to achieve the previously published BDCP Global Goals (BDCP 2012) identified in **Table 4**. While the selection of CRRs was integral to calculating Interim Survival Objectives that represent a meaningful contribution to recovery, it is the through-Delta survival rates assigned to the BDCP that constitute the Objectives.

The general approach to establishing these Interim Survival Objectives follows:

1. Compile life stage-specific survival estimates for each of the covered salmonids; sort by Sacramento and San Joaquin river populations;
2. Consolidate and reduce survival estimates to three life phases: Pre-Delta, Delta, and Post-Delta;
3. Populate an Excel spreadsheet model with pre-, through-, and post-Delta survival estimates and calculate CRRs (or more precisely 3-Year Replacement Rates) for each covered salmonid under current Delta conditions;
4. Solve for the through-Delta survival needed to achieve a CRR of 1.2 (1.3 for winter-run) after BDCP Year-19 , a CRR of 1.3 (1.4 for winter-run) after BDCP Year-28, and a CRR of 1.4 (1.5 for winter-run) after BDCP Year-40;
5. Take one-half of the necessary increase in Delta survival needed to meet these CRRs, add this to the baseline rate, and set the sum as the Interim Survival Objectives for each covered salmonid;
6. Assign responsibility for actions needed to achieve the Interim Survival Objectives to the BDCP. The remaining improvement in survival required to achieve the target CRRs (i.e., the balance after the BDCP survival improvement) is expected to accrue from other recovery actions implemented throughout the entire range of the species, and the percentage improvement will depend on the life phase affected.

The life stage-specific survival estimates were compiled from a variety of existing sources, including the NMFS winter-run Juvenile Production Estimate (JPE), recent acoustic tag survival studies, and trends in escapement and harvest records. Currently, the only empirical estimates of Delta survival are for Sacramento River late fall-run Chinook and San Joaquin River fall-run Chinook salmon; however, estimates based on acoustic tag studies for other Sacramento and San Joaquin species are expected to be available over the next five years. Where species-specific data were available they were used directly. More often, this was not the case, and adjustments were made based on how different life history characteristics would be expected to influence survival. In making these adjustments we assumed the following:

- Yearling migrants are expected to be actively smolting and will migrate more rapidly downstream through the Delta than will sub-yearling migrants. At a larger size smolts will also be less vulnerable to predation.

- The longer a salmonid life-stage resides in the Delta the higher the mortality.

- The later in the spring a salmonid life-stage transits the Delta the higher the mortality (because of warming temperatures and more active predators).

Specific examples of these kinds of adjustments were considered for steelhead spawning and rearing in Battle Creek and the American River. Battle Creek steelhead likely exhibit a lower tributary growth rate than American River steelhead, but exhibit higher survival to the smolt stage than do American River steelhead. In contrast, American River steelhead tend to smolt at a larger size, but exhibit lower tributary survival (Sogard et al. 2012). The larger-sized American River smolts would be expected survive Delta transit and ocean entry at a higher rate than the smaller Battle Creek steelhead smolts (Ward and Slaney 1988, Bond et al. 2008). While these kinds of assumptions and adjustments are no substitute for species-specific empirical data, they were necessary to constructing a life cycle context in which to approximate needed improvement to achieve sustainability and establish survival objectives.

Cohort replacement rates were used to establish a life cycle context for estimating changes in life stage-specific survivals needed to increase abundance and reduce risk, and to estimate the overall increase in Delta passage survival needed to achieve them. In their simplest form, CRRs use age-structured returns to calculate the number of returning adults in one generation produced by the previous generation. A CRR of 1.0 indicates a population is exactly replacing itself, not growing but also not declining in abundance. A CRR less than 1.0 indicates the population is not replacing itself and hence declining, and a CRR greater than 1.0 indicates the population is growing. For the purposes of establishing these Interim Survival Objectives we used the terms CRR and 3-Year Replacement Rates (3-YRRs) interchangeably, but acknowledge that to simplify this analysis we assumed an equal escapement of males and females, and assume all adults return at age 3. Neither of these assumptions markedly affect their use in our simplified model used to estimate the magnitude of needed life stage-specific improvements. We used CRRs of 1.2, 1.3, and 1.4 (1.3, 1.4, and 1.5 for winter-run) to calculate survival rates that need to be progressively achieved over the life of the BDCP, with check-ins at BDCP Year-19, -28, and -40. These CRR targets are generally accepted as representative of healthy population dynamics, but are not necessarily NMFS final recovery goals, and will be refined and revisited as further information becomes available. As noted above, one-half of the improvement in survival necessary to meet these CRR targets is expected to be achieved by the BDCP in the Delta.

The current cohort replacement rates for each covered salmonid were not explicitly matched to empirical data, but instead were set to levels below 1.0, but not so low as to predict rapid extinction of the species. This matches the slow but steady decline observed in these species over the last several decades. The San Joaquin species were an exception to this, as they had very low CRRs, largely due to the very low current Delta survival estimates used in the model. This suggests that the San Joaquin populations may currently be considered dependent populations, i.e., they are supported by a combination of hatchery fish, strays, and episodic successful natural reproduction.

Explicitly matching the predicted current cohort replacement rate to empirical data could be done in a future version of the model, but there are several challenges to doing so. One is to decide on the year or range of years of empirical data to match, and the CRRs for some species such as winter-run Chinook salmon have fluctuated greatly over the last 10-20 years. Another is to account for the large proportion of hatchery fish present in most escapement estimates, which is not currently part of the model. The large proportion of hatchery fish in most Central Valley salmonid species has the effect of keeping CRRs higher than they would be if the stock was solely comprised of naturally produced fish. The other effect is to increase the annual variation in escapement, as the return of hatchery fish stocked in the bays is largely dependent upon ocean survival, which can vary dramatically, as seen in the crash of Sacramento River fall-run Chinook salmon from 2007-2009.

With regard to incorporating inter-annual variability in the model, we considered using a method such as drawing a random number from a distribution with a specified mean and variance to the survival rates, both in the Delta and at other stages. Ultimately, we decided such an approach would still be focused around the mean survival rates, and since the shape of such a survival distribution is unknown at this time, it would require us to make more assumptions in a process that is already rich in assumptions, and would likely complicate the interpretation of the objectives without adding much value.

In selecting the specific CRRs for Year-19, Year-29 and Year-40 time steps, we also considered the relationships among the target CRRs and the previously established BDCP Global Abundance Goals for these species. In developing these projections we made the conservative assumption that the populations would respond slowly (i.e., remain near baseline CRRs) during the first 9 years following dual conveyance (BDCP Year-19). Beginning in BDCP Year-20 and extending for the next 20 years to BDCP Year-40, we estimated abundance based on the target CRR of 1.2 (1.3 for winter-run). Finally, we estimated abundance at BDCP Year-50, using the target CRR of 1.4 (1.5 for winter-run) for the period between BDCP year 41 and 50. The results of these projections and comparisons to the BDCP Global Abundance Goals are summarized in **Table 4**. Based on these projections, the estimated abundance of seven of the eight covered salmonids considered in this analysis would remain below their Global Abundance Goals at year 40, at which point abundance would be expected to increase rapidly over the next 10 years under a target CRR of 1.4 (1.5 for winter-run), leading to seven of the eight covered salmonids exceeding their global goal by the end of the BDCP permit period.

Of the eight covered salmonids, only the San Joaquin spring-run Chinook salmon was not projected to meet their global abundance target, but as there is no currently existing population, this projection is highly speculative. It is also clear from these projections that the future existence of naturally sustaining populations of San Joaquin River fall-run Chinook salmon and steelhead is uncertain. To the extent that our current placeholder survival estimates and CRRs are generally accurate, five additional generations at CRRs well below replacement would place both populations at high risk of extirpation. However, NMFS anticipates more immediate improvements in survival of San Joaquin-origin Chinook salmon and steelhead to accrue based on early conservation actions, including RPAs required by the NMFS and U.S. Fish and Wildlife Service Biological Opinions, improved Delta inflows, habitat restoration projects such as Dutch Slough, and improvements in water quality from the upgraded Sacramento Regional Wastewater Treatment Plant.

Finally, among ESA listed species, it is an exceptionally rare circumstance for a single factor affecting a single life stage to be a survival bottleneck such that eliminating the bottleneck will put the species on a trajectory to recovery, and the role of Delta survival in the demise of CV Chinook salmon and steelhead is no exception. However, because it is well established that the magnitude of mortality during Delta passage can be high (e.g., Brandes and McLain 2001, VAMP studies), it is highly unlikely that CV salmonids can be recovered without major improvement in Delta survival. This is particularly the case for salmon and steelhead emigrating from the San Joaquin River and transiting the southern Delta. In recognition that the BDCP cannot be responsible for producing the entire increase in survival deemed necessary to achieve sustainability, these Interim BDCP Survival Objectives are approximately one-half of the estimated overall improvement needed to achieve the long term CRR targets. This is based on the assumption that other restoration and recovery efforts will result in substantial improvements in survival throughout the salmonids range.

INTERIM SURVIVAL OBJECTIVES

Because salmonids emigrating from the Sacramento and San Joaquin rivers enter the Delta at different locations, they traverse the Delta via different routes, and are subject to different sources and magnitudes of mortality. Accordingly, baseline survival estimates and survival objectives are considered separately for the different watersheds. Further, because improvements in Delta survivals are expected to accumulate over time, survival objectives are presented in multiple time steps during the expected 50-year timeline of the BDCP: BDCP Year-19 (19 years after the signing of the BDCP ROD and 9 years after the start of dual conveyance); BDCP Year 28 (9 years or 3 fish generations after the initial time step); and BDCP Year-40 years (12 years or 4 fish generations after the second time step when many of the habitat restoration and other BDCP benefits are expected to be realized throughout the Delta.

Table 5 presents the Interim Juvenile Salmonid Delta Survival Objectives for Chinook salmon and steelhead originating in the Sacramento and San Joaquin rivers, respectively.

Current Delta survival estimates for Chinook salmon and steelhead originating in the Sacramento River range from 0.35 to 0.50 (Michel, 2010; Perry et al. 2009; Perry 2010; Perry et al. 2012a; Perry et al. 2012b). The calculated Interim Survival Objectives for Sacramento River winter-run Chinook salmon are 0.52, 0.54, and 0.57 for the BDCP Year-19, Year-28, and Year-40 time steps, respectively.

For Sacramento River spring-run Chinook salmon, the calculated Interim Survival Objectives are 0.49, 0.52, and 0.54 for the BDCP Year-19, Year-28, and Year-40 time steps. The calculated Interim Survival Objectives for fall-run Chinook are 0.42, 0.44, and 0.46 for the same respective time steps. Finally, Interim Survival Objectives for Sacramento late fall-run Chinook salmon are 0.49, 0.51, and 0.53 for the same BDCP Year-19, Year-28, and Year-40 time steps.

For steelhead, we initially calculated Interim Survival Objectives for the American River and Battle Creek populations separately, based on expected differences associated with life history variation. However, as noted above we used the Battle Creek population to be representative of the Sacramento River steelhead as they are the most likely to be used to monitor survival. For the Battle Creek population of steelhead the current survival was set at 0.45 and the calculated Interim Survival Objectives were 0.54, 0.56, and 0.59 for the BDCP Year-19, Year-28, and Year-40 time steps.

Current Delta survival rates for Chinook salmon and steelhead originating in the San Joaquin River range from 0.05 to 0.10. For San Joaquin River fall-run Chinook salmon the current survival was set at 0.05 and the calculated Interim Survival Objectives were 0.27, 0.29, and 0.31 for the BDCP Year-19, Year-28, and Year-40 time steps, respectively. For San Joaquin River spring-run Chinook salmon the estimated initial survival is 0.7 and the Interim Survival Objectives are 0.33, 0.35, and 0.38 for the BDCP Year-19, Year-28, and Year-40 time steps. For San Joaquin River steelhead, the current survival was set at 0.10, and the calculated Interim Survival Objectives were 0.44, 0.47, and 0.51 for the same BDCP time steps.

There are several other factors that might be considered in further defining or revising these Interim Survival Objectives, including scaled objectives based on wet and dry years. However, at this point we are reluctant to more finely define or scale survival objectives until additional species-specific survival estimates are collected over a range of hydrologic conditions. However, as new information becomes available, the potential to define wet- and dry-year expectations should be revisited.

Climate change was not explicitly considered in developing these Interim Survival Objectives, but it may necessitate changes in the objectives at some future point. For example, if higher river temperatures reduce instream survival or ocean survival decreases, then higher Delta survival would be required to maintain the status quo.

ACHIEVABILITY OF INTERIM DELTA SURVIVAL OBJECTIVES

Although the use of this simple life stage-specific deterministic model and target CRRs facilitated defining Interim Survival Objectives in a life cycle context, it does not address how achievable these objectives are within any one specific life stage, and particularly the through-Delta life stage. It is obviously important to set objectives that are consistent with putting these populations on a trajectory of sustainability, but unless these objectives are reasonably achievable they have limited value. To address this question, we reviewed preliminary analyses conducted by Chuck Hanson (Hanson Environmental, Inc.) which evaluated a time series of previous Delta survival estimates and relationships between those survival estimates and CRRs. Hanson conducted separate analyses for San Joaquin River-origin fall-run Chinook salmon and Sacramento River-origin fall-run Chinook salmon.

For fall-run Chinook salmon originating in the San Joaquin River and tributaries, Hanson used Delta survival estimates based on VAMP CWT tag recoveries in the Chipps Island trawl and in ocean fisheries between 1995 and 2006. These data included through-Delta survival estimates that in some years exceeded the Interim Survival Objectives for San Joaquin fall-run Chinook salmon, thus substantiating that they had been historically achieved. Moreover, his analyses showed a positive correlation between Delta survivals and CRRs, and the time series of 5-year geometric mean CRRs between 1999 and 2007 (0.27 to 1.68) included CRRs in the range of 1.2 -1.4 that we used as target CRRs to estimate Delta survival improvements.

Hanson's preliminary analyses of Delta survival of fall-run Chinook salmon originating in the Sacramento River and tributaries were also based on CWT recoveries. However, these survival estimates were based on survival indices rather than absolute survivals, and release locations in the Sacramento River were more variable than the uniform release location at Mossdale used for the San Joaquin River. Despite these differences, his conclusions were largely the same. Between 1996 and 2010, survival estimates for several release groups of fall-run Chinook salmon exceeded the Interim Delta Survival Objective of 0.42 and 0.46, again indicating that they are achievable. Further, although the 5-year geometric mean CRRs for Sacramento River fall-run Chinook have mostly been below the BDCP Year-19 CRR target of 1.2, the CRRs ranged from about 1.2 to 2.0 between 1993 and 2002, thus validating the achievability of our 1.2 to 1.4 CRR targets. In additional exploratory analyses, Hanson calculated 5-year geometric mean CRRs for spring-run Chinook during the period 1975 to 2008 that exceeded 1.2. Similarly, he identified a 12-year period in the 1990s and early 2000s during which 5-year geometric mean CRRs for winter-run Chinook ranged from 1.2 to over 2.5.

ESTIMATED CONTRIBUTION TO RECOVERY

Few if any ESA listings are the result of a single physical, chemical, or biological factor, and decline of Central Valley salmonids is no exception. Further, there is no requirement or expectation that this or any Habitat Conservation Plan will address, let alone resolve, all of the factors causing a species' decline. However, there is a requirement that a Habitat Conservation Plan will demonstrably contribute to the recovery of a covered species.

By using CRR targets of 1.2, 1.3 and 1.4 (1.3, 1.4, and 1.5 for winter-run) for the BDCP Year-19, -28, and -40 time steps, and then using 50% of the estimated Delta survival improvements needed to achieve these CRR as the Interim Survival Objectives, NMFS is ensuring that these objectives will make a substantive contribution to recovery. For winter-run Chinook salmon we selected CRRs of 1.3, 1.4, and 1.5 as this population is listed as endangered under the ESA, and is currently at very low escapement levels. Because of these low initial escapement levels, population projections using lower CRRs of 1.2, 1.3, and 1.4, respectively resulted in population estimates that were still well below the global abundance objective after 50 years. It is also reasonable to expect BDCP to achieve higher rates of improvement for winter-run Chinook salmon because their needs were heavily considered in the design of many of the conservation measures proposed in the BDCP, including the North Delta Bypass rules, the Yolo Bypass improvements, and temperature and flow requirements in the Sacramento River below Keswick Dam.

MONITORING AND EVALUATION AND ADAPTIVE MANAGEMENT

Because of the limited availability of empirical information to inform the development of the initial baseline survival estimates, NMFS used data from recent acoustic tag survival studies of hatchery-reared late fall-run Chinook salmon as a starting point from which to estimate baseline survival for the remaining salmon and steelhead populations. NMFS acknowledges the limitations of this approach, but in balancing the risks to ESA-listed species, we considered it better to proceed with interim targets and recognize the need to periodically review these baseline estimates and document progress toward the 19-, 28, and 40-year objectives. As new empirical survival estimates for CV species become available, NMFS is prepared to review and revise these Interim Juvenile Salmonid Delta Survival Objectives as appropriate. For example, Philip Sandstrom (University of California at Davis, personal communication) has recently completed an acoustic tagging study of Sacramento River steelhead that will help inform estimating steelhead survival in the Delta. In addition, Sean Hayes (NMFS, SWFSC Lab, personal communication) is scheduled to begin a winter-run Chinook salmon acoustic tagging study in the Sacramento River beginning in 2013. Further, the USBR has recently initiated acoustic tagging studies with steelhead in the San Joaquin River. Data from several years of acoustic tagging studies of San Joaquin fall-run Chinook salmon are expected to be available shortly. All of these studies are expected to greatly improve not only the estimates of baseline survival in the Delta for these populations, but also allow a more focused consideration of operations and conditions that can contribute to improvements in survival.

There remain numerous questions regarding factors that limit survival of juvenile salmonids migrating in the Sacramento and San Joaquin rivers. Empirical data on juvenile survival in both the pre-Delta and post-Delta stages is lacking for many species. BDCP monitoring should include programs to estimate survival from the fry-to-smolt and smolt-to-adult stages. Counting juveniles produced upstream will require rotary screw traps with efficiency estimates, and will likely require novel methods to estimate steelhead parr and smolt numbers. Central Valley hatchery programs should routinely estimate smolt to adult return rates (SARs) for each smolt class, and consider both adults returning to the hatchery and spawning in the river. One often noted but neglected question is whether improved rearing habitat in the Delta could lead to longer residences times and lower survival rates for juvenile salmonids, but be offset by the survivors being larger and exhibiting higher ocean survival rates. The analytical framework we introduce here is flexible enough to accommodate such a change by adjusting the post-Delta survival element of the equation, which will lower the required though-Delta survival needed to reach the same long-term goal, and result in lower BDCP Delta survival objectives.

Future work should also include development of methods to incorporate new recovery actions attributable to habitat restoration and other recovery activities into models that can contribute information to updating these BDCP Interim Juvenile Salmonid Survival Objectives. One particularly important near-term step to implementing the BDCP Juvenile Salmonid Survival Objectives will be developing regional agreements on geographic boundaries for estimating through-Delta survivals, and appropriate technologies for collecting the required empirical data.

Finally, it is imperative that all of the stakeholders with an interest in the Delta, whether it is viewed primarily as a source of water or as an ecosystem supporting threatened and endangered species (or both), continue to work collaboratively to establish a monitoring program to improve the accuracy and precision of through-Delta survival estimates and monitor progress toward achieving these Interim Survival Objectives. This will require, at a minimum, establishing a more expansive network of acoustic arrays for monitoring Delta entry and exit and identifying survival bottlenecks, and deployment of more efficient trapping systems to better understand the numbers and timing of naturally migrating juvenile salmonids.

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Table 2. Life history summaries highlighting timing and duration of Delta residence, and fish size during Delta passage. Information compiled from Vogel and Marine (1991), Fisher (1994) and Williams (2006).

Population/Species	Spawning	Average fecundity	River rearing and juvenile migration	Delta residence and duration	Size in Delta (mm FL)	Ocean residence	Adult migration
Winter-run Chinook	May through August	5,232	July through March	November through April	60-130mm	2 to 3 years 91% return at age-3	January through May
Spring-run Chinook	August through October	5,300	November through April	Fry: Dec-Feb Smolts: Mar-May	Dec-Feb: 36-79mm Mar-May: 68-132mm	3 years; 74% return as age-4 to Butte Creek	March through August
Fall-run Chinook	October through December	4,497	January through June	December through March	35-90mm	2 to 5 years Most return at age-3	July through December
Late fall-run Chinook	January to March	4,600	April thru December	Smolts: Oct-Feb Fry: April-May	Oct-Feb: 80-191mm April-May: 31-38mm	2 to 4 years 57% return at age-3; 41% return at age-4	November through March
Steelhead	Jan through April	5,000	Rear entire year in rivers. Emigrate in Jan-June (peak is Feb-April)	(Days to weeks) No good evidence that they rear in the Delta	150-350mm (most 200-300mm)	1-3 ocean years at maiden spawning	Spawners: Sept-April Kelts: Jan-May

Table 3. Pre-Delta, Delta, and post-Delta survival estimates use to estimate initial Cohort Replacement Rates

Watershed	Species	ESU/DPS/population	Pre-Delta	Delta	Post-Delta
Sacramento River and Tributaries	Chinook salmon	Winter-run	0.0365	0.40	0.0226
		Spring-run	0.0432	0.40	0.0198
		Fall-run	0.056	0.35	0.0198
		Late fall-run	0.0367	0.40	0.0245
	Steelhead	Sacramento	0.0214	0.45	0.0360
San Joaquin River and Tributaries	Chinook salmon	Fall-run	0.0564	0.05	0.0226
	Chinook salmon	Spring-run	0.0432	0.07	0.0198
	Steelhead	San Joaquin	0.0257	0.10	0.0360

4. Projected change in abundance of CV salmonids under the 1.2,1.3 and 1.4 CRR targets after 19,28,40, and 50 years (1.3, 1.4, and 1.5 for winter-run Chinook salmon), and their relation to the BDCP Global Goals. The global goal for fall-run Chinook salmon is 750,000 total for Central Valley.

Species	Time (yrs)	Conveyance	No. Generations	CRR	Delta Survival	Initial Size	Ending Size	Global Goal (naturally spawned)
Sac winter-run	1-10	single	3.3	0.86	0.40	1,153	556	
Sac winter-run	11-19	dual	3.0	1.08	-	709	895	
Sac winter-run	20-28	dual	3.0	1.30	0.63	895	1,953	
Sac winter-run	29-40	dual	4.0	1.40	0.68	1,953	7,413	
Sac winter-run	41-50	dual	3.3	1.50	0.73	7,413	28,795	23,800 by 2060
Sac spring-run	1-10	single	3.3	0.91	0.40	7,422	5,363	
Sac spring-run	10-19	dual	3.0	1.05	-	5,363	6,274	
Sac spring-run	20-28	dual	3.0	1.20	0.59	6,274	10,845	
Sac spring-run	29-40	dual	4.0	1.30	0.64	10,845	30,794	
Sac spring-run	41-50	dual	3.3	1.40	0.68	30,794	93,651	59,000 by 2060
Sac fall-run	1-10	single	3.3	0.88	0.35	100,291	65,430	
Sac fall-run	10-19	dual	3.0	1.04	-	65,430	73,775	
Sac fall-run	20-28	dual	3.0	1.20	0.48	73,775	128,091	
Sac fall-run	29-40	dual	4.0	1.30	0.52	128,091	363,269	
Sac fall-run	41-50	dual	3.3	1.40	0.56	363,269	1,121,028	562,500 by 2060
Sac late fall-run	1-10	single	3.3	0.85	0.40	11,000	6,348	
Sac late fall-run	10-	dual	3.0	1.00	-	6,348	6.820	

	19							
Sac late fall-run	20-28	dual	3.0	1.20	0.57	6,820	11.798	
Sac late fall-run	29-40	dual	4.0	1.30	0.62	11,798	33,821	
Sac late fall-run	41-50	dual	3.3	1.40	0.67	33,821	104,295	68,000 by 2060
Sac Steelhead	1-10	single	3.3	0.87	0.45	7,600	4,699	
Sac Steelhead	10-19	dual	3.0	1.00	-	4,699	5,202	
Sac Steelhead	20-28	dual	3.0	1.20	0.63	5,202	9,064	
Sac Steelhead	29-40	dual	4.0	1.30	0.68	9,064	25,772	
Sac Steelhead	41-50	dual	3.3	1.40	0.73	25,772	79,566	11,000 by 2060
SJ Spring-run	1-10	single	3.3	0.16	0.07	1,000	2	
SJ Spring-run	10-19	dual	3.0	1.00	-	1,000	1,000	
SJ Spring-run	20-28	dual	3.0	1.20	0.59	1,000	1,729	
SJ Spring-run	29-40	dual	4.0	1.30	0.64	1,729	4,940	
SJ Spring-run	41-50	dual	3.3	1.40	0.69	4,940	15,169	30,000 by 2060
SJ Fall-run	1-10	single	3.3	0.13	0.05	5,754	6	
SJ Fall-run	10-19	dual	3.0	1.00	-	5,754	5,754	
SJ Fall-run	20-28	dual	3.0	1.20	0.48	5,754	9,928	
SJ Fall-run	29-40	dual	4.0	1.30	0.52	9,928	28,265	
SJ Fall-run	41-50	dual	3.3	1.40	0.56	28.265	86,710	187,500 by 2060
SJ Steelhead	1-10	single	3.3	0.16	0.07	300	1	
SJ Steelhead	10-19	dual	3.0	1.00	-	300	300	
SJ Steelhead	20-28	dual	3.0	1.20	o.59	300	519	
SJ Steelhead	29-	dual	4.0	1.30	0.64	519	1,484	

	40							
SJ Steelhead	41-50	dual	3.3	1.40	0.69	1,484	4,561	1,700 by 2060

Table 5. Sacramento-San Joaquin through-Delta Salmonid Survival Objectives. For each species, we estimated current through-Delta survival rates, the Delta survival rates needed to meet a CRR of 1.2 and 1.4 (1.3 and 1.5 for winter run), and the interim Delta survival objectives. The interim Delta survival objectives are the current survival rate plus one half of the increase in survival rate required if Delta survival alone was used to achieve the CRR targets.

Species	Population	Estimated Current Through-Delta survival	Delta Survival Rate to Achieve CRR's after 19, 28, and 40 years	Interim Delta Survival Objectives after 19, 28 and 40 years
Chinook salmon	Sac winter-run	0.40	0.63; 0.68; 0.73	0.52; 0.54; 0.57
	Sac spring-run	0.40	0.59; 0.64; 0.68	0.49; 0.52; 0.54
	Sac fall-run	0.35	0.48; 0.52; 0.56	0.42; 0.44; 0.46
	Sac late fall-run	0.40	0.57; 0.62; 0.67	0.49; 0.51; 0.53
	SJ fall-run	0.05	0.48; 0.62; 0.67	0.27; 0.29; 0.31
	SJ spring-run	0.07	0.59; 0.64; 0.69	0.33; 0.35; 0.38
Steelhead	Sacramento	0.45	0.63; 0.68; 0.73	0.54; 0.56; 0.59
	San Joaquin	0.10	0.78; 0.85; 0.91	0.44; 0.47; 0.51